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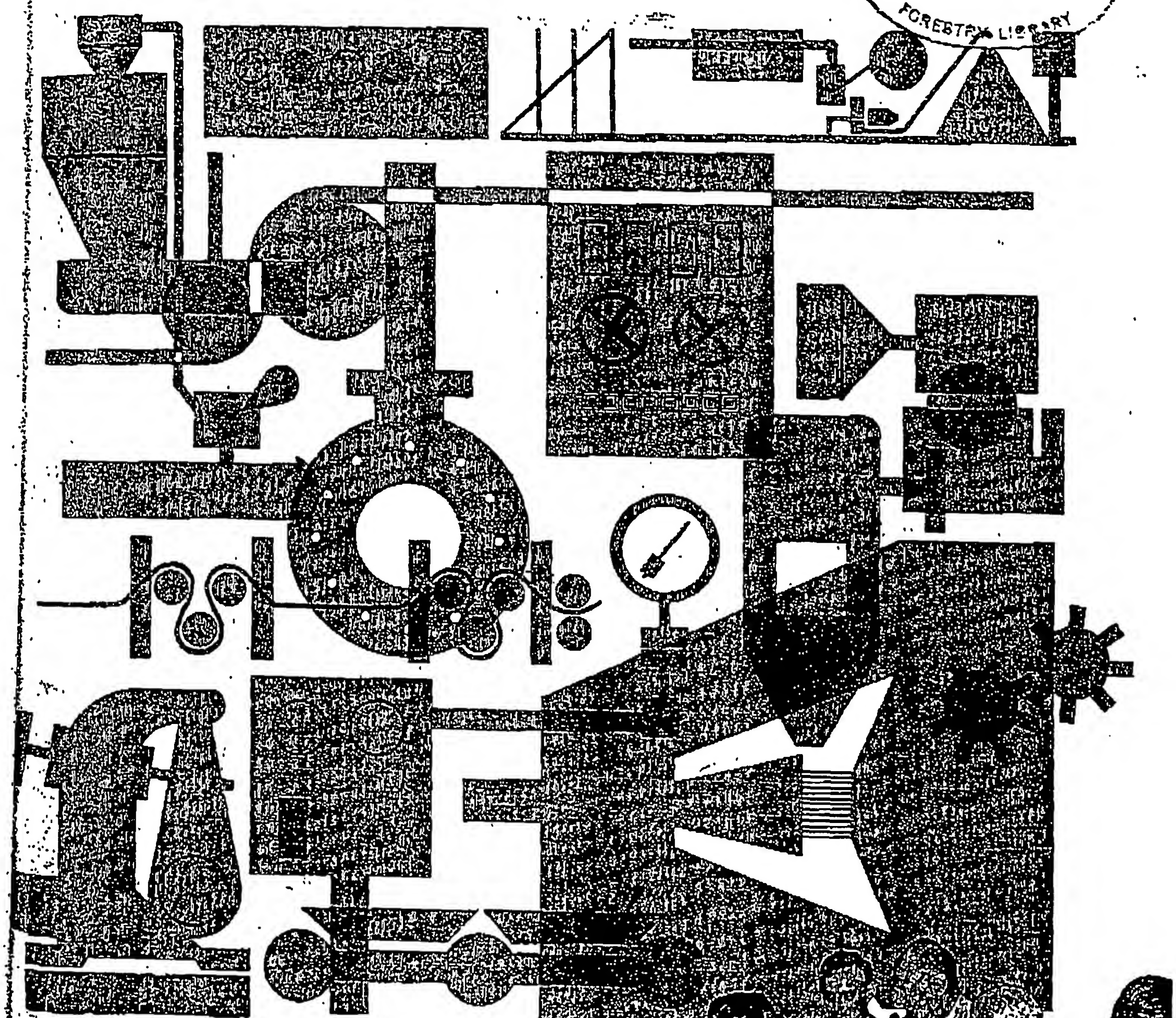

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Development of a Unique Lightweight Paper

Abstract: A unique, functional 47 g/m² paper for use in xerographic, offset, and mimeograph equipment has been developed to commercialization. The paper has a bulk in the range of 75 g/m² bond and xerographic sheets. This bulky, yet light structure, is obtained by adding small quantities of thermoplastic microspheres to the web at the paper machine fan pump, the spheres expanding 5–10 times in diameter in the machine dryer section. A coating to provide the required stiffness, frictional, fusing, and electrical properties is applied at the size press. All but very minimal calendering has to be avoided. The paper is rotary cut and packaged in an automatic packaging machine. Dimensional and ream requirements equal to 75 g/m² xerographic sheets are being met in mill operation.

Keywords: Product development · Lightweight papers · Electrostatic copying · Sheets · Microspheres* · Expansion · Compressibility · Paper · Stiffness · Toner fusing* · Rotary cutting*

In order to effectively counteract the increasing trends in mailing costs, to reduce shipping costs, and to permit easier handling, a reliable, lightweight (40–50 g/m²) xerographic sheet, performing well in offset and mimeographic use as well, is needed. Further, the utilization of lightweight sheets to perform the functions of heavier weight sheets of identical surface areas seems to be a logical step towards reducing the increasing pressure on our natural resources and easing our solid waste disposal problems.

Functionally, the problem with existing sheets in the 40–50 g/m², and even higher, basis weight ranges is that their rather low stiffness levels, frequently combined with undesirable curl characteristics, do not permit sufficiently reliable performance in xerographic machines and necessitate adjustments and slowdowns in the smaller sheet-fed offset presses. At a basis weight of 75 g/m², the more conventional sheet, designed correctly, works well, so our task lay in imparting several key properties of the conventional sheet to one only slightly more than half the weight.

After considering and examining various approaches toward higher stiffness levels, work involving the addition of thermoplastic microspheres to the paper web was initiated: These thermoplastic microspheres are copolymers of vinylidene chloride and acrylonitrile, which, incorporating isobutane as an expanding or "blowing" agent, expand the sheet to a very light yet bulky structure. In their unexpanded state, the microspheres have a diameter of approximately 5–8 μ, while the expanded diameter is about 25–40 μ. Expansion takes place at either 65°C or 95°C, depending on the type of sphere used. One type is an unblown dry powder for expansion in the paper web itself, while another is activated in a foam generator prior to addition to the papermaking slurry. Our early work took place with the generator blown spheres because of the unavailability of the other version at that time. In either version, the spheres are added at the machine fan pump. These expanded spheres in a paper web may be seen in Figs. 1–3, which represent electron microscope magnifications of microsphere paper at 100×, 500×, and 1000× magnification, respectively.

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EARLY DEVELOPMENT EFFORTS AND CONSIDERATIONS

Our first run, using a pilot paper machine, occurred early in 1969. Important considerations included the requirements for optimum performance in xerographic machines. Briefly stated, these involve a reasonably smooth sheet surface for a satisfactory level of toner fusing to paper, absence of scorching tendencies, a high beam strength (stiffness), a low level of curl, good surface strength, a controlled moisture content level, controlled conductivity level, and well controlled sheet and ream dimensions, with a very minimum of finishing induced ream defects. The lightweight paper had to meet all of the finishing requirements of our 75 g/m² basis weight xerographic grades. Additionally, it had to perform well in three diverse xerographic fusing systems—one with a radiant heater, one with an oven-type heater, and one with a heated roll fuser. It had to work in xerographic machines with vacuum feed and friction feed configurations, as well as in offset and mimeograph equipment.

The first trials utilized a combination hardwood sulfite-softwood kraft furnish, with TiO_2 and clay as fillers and an ethylated starch surface size. Microsphere addition levels between 0 and 9% were tried. The initial trial showed that:

1. Very bulky lightweight sheets can be produced with the microspheres.
2. The relatively rough (ca. 300 Sheffield) sheets fused much better than equivalent non-microsphere 300 Sheffield sheets, although not to our full satisfaction.
3. Calendering, except for very nominal levels, had to be avoided as the microspheres were crushed and the caliper increase lost. This is shown in Fig. 4.

However, the paper exhibited an unsatisfactory level of curl, scorch, sphere dusting, and surface strength, as well as static and frictional problems.

SHEET DESIGN AND DEVELOPMENT

Sheet design and development work with a mill that had obtained the exclusive rights to microspheres for our and related applications was started in mid-1969, with the small early runs again bringing to light many of the problems noted previously. The microsphere distribution

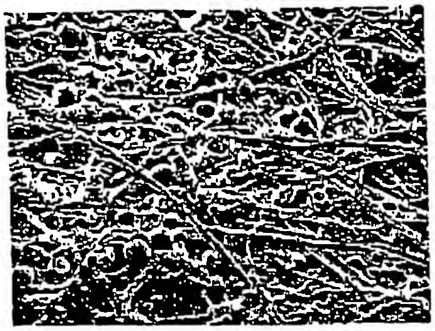

Fig. 1. Expanded microspheres in paper web; 100× magnification.

Fig. 2. Expanded microspheres in paper web; 500× magnification.

Fig. 3. Expanded microspheres in paper web; 1000× magnification.

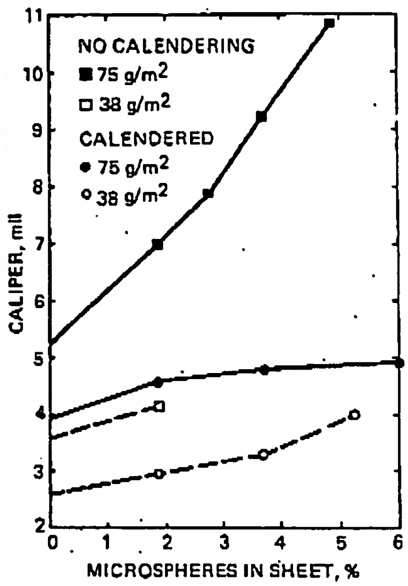

Fig. 4. Effect of calendering on caliper.

Table I. Physical Data—Microsphere Paper vs. 75 g/m² Basis Weight Xerographic/Offset Paper

	Microsphere paper	*75 g/m² Basis weight sheet (Xerox 1524 paper)*
Basis weight, g/m²	47	75
lb/17 × 22–500	12.5	20.0
Caliper, mil	4.25	4.20
Density, gms/cc	0.44	0.71
Taber V-5 stiffness, MD	1.20	2.48
CD	0.60	1.25
Stiffness index, CD	1.25	1.03
Sheffield smoothness, WS	285	140
FS	270	135
Opacity, % Huygen	80.0	88.0
Brightness, % IPC	83.2	83.0
Ream moisture content, %	4.0	4.7
Gurley porosity, sec/100 cm³	32.0	18.0
Tensile strength, lb/in., MD	18.9	28.0
CD	10.6	13.0
% Stretch, MD	2.32	2.05
CD	6.07	3.00
Burst strength, psi	18.1	23.8
Tear, g MD	31	56
CD	32	70
MIT fold, MD	111	68
CD	60	25
Wax pick, W	18	16
F	14	14
Coefficient of friction S/K[a]	0.55/0.48	0.58/0.45

[a] S and K refer to the static and kinetic coefficient of friction, respectively. Test run per ASTM D1894-63 (1963). American Standard K65 14-1965.

within a sheet at a basis weight of about 45 g/m² and a caliper of 4–4.5 mil was not uniform. A higher concentration was formed on the top than on the wire side, as sh wn in Figs. 5 and 6. Fusing in our roll fuser machines was questionable, the scorch level was unacceptable, and the paper was not functional because of a high incidence of double and multi-sheet feeding and because of high curl levels. Investigations revealed that the poor electrical and frictional properties were largely a result of the predominance of microspheres on the top side, where they were insufficiently covered by the conventional surface sizing applications used. Additional work revealed the multi-sheet feeding problem to be largely caused by the electrostatic attraction between sheets created in the stack by the feed rollers feeding, or attempting to feed, paper. In addition, we were unable to cut the reams satisfactorily in guillotine cutting—specification tolerances were not met because of the higher compressibility of the sheet, and occasional edge padding was noted as well. In order to isolate sheet finishing variables from sheet design factors, a decision was made to rotary cut further runs.

At the same time, a laboratory study was initiated, with active participation by the supplier, to develop a surface sizing formulation t vercome the problems cited. Well over 50 combinati ns were investigated and their effects determined. Two formulations, incorporating a latex, a polymer binder, and other ingredients, were chosen for on machine application. Meanwhile, mill work to improve the microsphere addition system and to define process variables was proceeding. During the next period, a switch was made to the internally blown microspheres and the new surface sizing refined. The resultant sheet gave us definite indications of commercial success. We found the two-sidedness notably reduced and the frictional characteristics to be in the "normal" range for xerographic paper (Table I). Fusing was acceptable. The internally blown spheres proved satisfactory for increasing caliper. The curl level, while improved, was still unacceptable in portions of the runs, and the overall variability was in excess of what we felt could be tolerated.

FINAL DEVELOPMENT AND COMMERCIALIZATION

The final development phase involved:
1. A change to a larger paper machine for production capacity considerations, elimination of the sporadic curl problems noted, and utilization of the better overall system.
2. The installation of a new rotary cutter/automatic packaging line to finish the sheet.

Much effort was spent by the mill in several small runs to optimize the system and the paper machine. After operational variables had been identified and optimized, the microsphere paper was found to be a very runnable sheet and no more difficult to make than higher-weight papers. Predictive testing methods to relate the sheet off the machine to its final use requirements were determined and in-mill xerographic machine test procedures established.

The finishing line, which recently went on stream, consists of a 5-pocket Lenox cut size sheeter, feeding a Model 66 Pemco wrapper. The rotary cutter has a 4-roll backstand, utilizing 45-in. rolls of approximately 800 lb on 5-in. cores. The sheets are wound individually through bar-type curl breakers and then fed through a conventional Lenox slitting and cutting system. The reams are wrapped without stiffeners in a moisture barrier protective 30-15-30 wax laminate wrapper. Ream height of the 4.25-mil sheet is around 2–2.2 in. Some modifica-

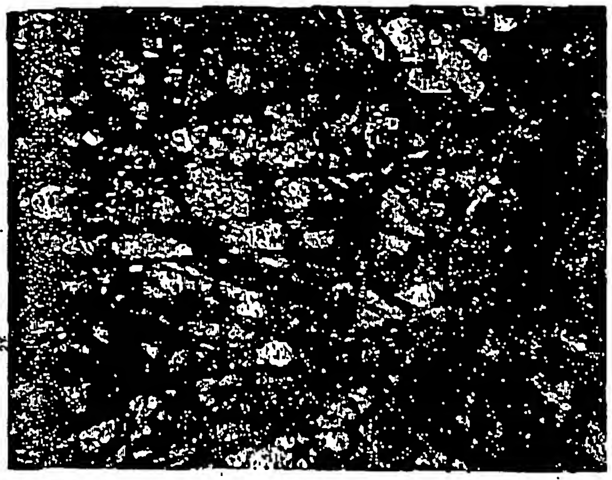

Fig. 5. Microspheres distribution within sheet on the wire side.

Fig. 6. Microspheres distribution within sheet on the felt side.

tions of the rotary cutter-packaging machine transfer station were made to eliminate rough starts and stops causing ream interfaces and subsequent damage in wrapping. The automatic packaging unit was tuned for this sheet and moisture barrier wrapper with help from the equipment suppliers.

Care in handling the microspheres ream is necessary throughout the entire operation. The sheet can be damaged more easily, and the damage can cause end use problems. The finishing of the paper at this point is quite satisfactory and very nearly equivalent to the levels of our 75 g/m² basis weight product, despite the more critical nature of handling this sheet.

CHARACTERISTIC OF THE MICROSPHERE SHEET

Table I shows the physical properties of the microsphere paper, compared to one of our 75 g/m² basis weight xerographic sheets of nearly equal caliper. The density differences of the two sheets are revealing.

The Taber V-5 stiffness instrument was used for stiffness measurements. The Stiffness Index,[1] calculated from the Taber V-5 values, represents the inherent stiffness of the paper made by a specific process and of a specific formulation. It was found to be indicative of the stiffness obtainable from a particular composition sheet for satisfactory end use performance.

The microsphere paper is considerably rougher than the 75 g/m² basis weight sheet, yet the fusing characteristics of the two papers are very similar. We utilize several fusing tests. One of the more common ones involves the use of a Taber abrader equipped with a 375-g weight to abrade a specific image, fixed at specific

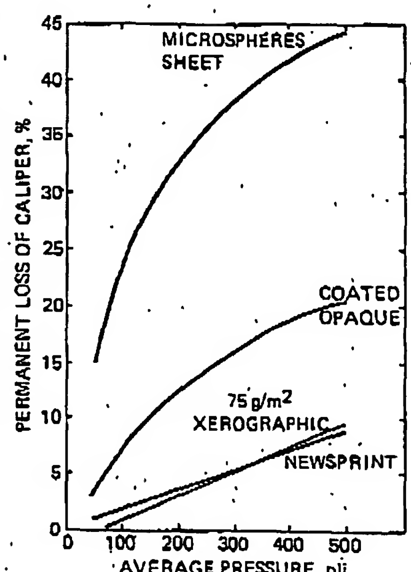

Fig. 7. Permanent caliper loss.

conditions on the sheet, to a 20% image loss, as measured by a Welch Densichron unit, counting the number of cycles to do this.

Referring to Table I, the two sheets have similar brightnesses, whereas the opacity of the 47 g/m² basis weight sheet is about 8 units lower. Ream moisture content of the lightweight paper is lower, mainly for paper machine runnability reasons.

The cross-directional stretch values of the microsphere paper should be noted, they are about twice that of the higher-weight paper. The machine direction stretch values of the two sheets have shown about a 10% difference. As a practical implication, somewhat lower stresses have to be put on the paper in the finishing operation. While the spheres themselves have no affinity for cellulose and their addition usually weakens the paper web to some extent, it should be noted that the physical data for the microsphere paper by no means indicate a weak sheet.

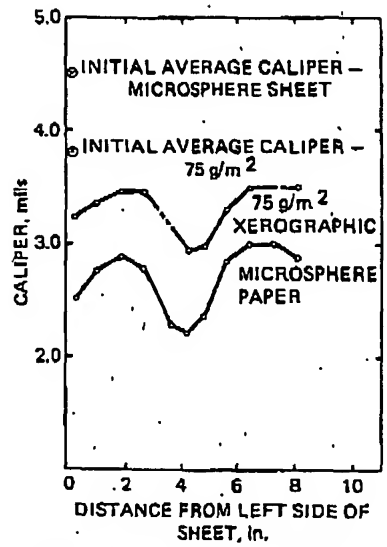

Fig. 8. Pressure profile at 500 pli.

Sheet compressibility and calendering were referred to earlier. Tests run with 4 papers—a matte coated opaque printing paper, a 75 g/m² basis weight xerographic paper, a newsprint sheet, and microsphere paper—in a laboratory fixture determined the results at given pressures. This is shown in Figure 7. The microsphere paper showed a higher caliper loss than any of the other sheets throughout the pressure range shown. It is interesting to note that the laboratory fixture had a very definite crown and pressure nonuniformity across the nip, shown in Fig. 8.

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The author would like to credit our supplier and the entire paper development team at Xerox. For special mention, Charles Green and Bob MacClaren of Xerox Paper Development should be cited. Mr. Green for his work on surface sizings technology and overall efforts on the project, and Mr. MacClaren for his enthusiasm, endeavors, and backing, without which this new concept would not have become a reality.

[1] C. Green, Paper Development Dept., Xerox Corp., Unpublished results.